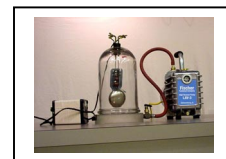


Activity #3

Title: Transmission of Longitudinal (sound) Waves-Teacher's Version



(Student Lab Activity with Teacher Demonstration)

Lab teams of four students will be required for this activity.

National Standards addressed: *INTERACTIONS OF ENERGY AND MATTER*

Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.

Purpose: Students will develop an understanding that matter, in some form, is necessary for longitudinal (sound) waves to be propagated. If no matter is present (i.e., in a vacuum) with which to interact, energy transfer is impossible.

Materials Needed: several coat hangers (one for each team of four students), several 75 cm strings (one for each team of four students), metal laboratory table support rod (or similar metal rod/tube approx. 1 meter in length and 2-3 cm in diameter), wind up pocket watch wrist watch or alarm clock, vacuum pump/bell jar assembly, battery-operated or wind-up alarm clock (or bell, buzzer, etc.)

Materials Sources:

- **Support rod** (stainless steel, 38"): Frey Scientific, 100 Paragon Parkway, P.O. Box 8101, Mansfield, OH 44903---2002 catalogue, pg. 646, #15564748, \$17.75
- **High vacuum pump:** Frey Scientific, 100 Paragon Parkway, P.O. Box 8101, Mansfield, OH 44903---2002 catalogue, pg. 757, #15562522, \$563.00
- **Vacuum pump plate:** Frey Scientific, 100 Paragon Parkway, P.O. Box 8101, Mansfield, OH 44903---2002 catalogue, pg. 757, #15562519, \$210.00
- **Bell jar:** Frey Scientific, 100 Paragon Parkway, P.O. Box 8101, Mansfield, OH 44903---2002 catalogue, pg. 757, #15590805, \$126.85.....OR the vacuum pump plate and bell jar can be replaced with the "**Bell in Vacuum**," item # 15570533, pg. 765 at reasonable cost of \$39.95

Procedure:

1. **(Teacher-directed)** Have your students form a hypothesis by ranking the phases of matter (solid, liquid and gas) according to their ability to carry sound-- from the poorest to the best BEFORE performing any of the following demonstrations. **Most students will choose gases (air) as being the best conductor of sound simply because it is the most common medium through which sounds are detected by humans. The subsequent demonstrations will prove otherwise.**
2. **(Teacher demonstration)** Place the ticking pocket or wristwatch about a meter away from a volunteer student's ear. It is very unlikely that any sound from the watch will be detected. Now press the back of the watch to one end of the metal support rod and have the student gently touch the opposite end to his ear. The sound of the watch is now quite audible—indicating that sound travels better through solids than through air. (Most other students will want to try this as well.)
3. **(Student lab team activity)** Tie loops (large enough to insert one's fingers) in each end of the 75 cm string. Hang the coat hanger (by its "hook") in the middle of the string. Holding both string loops in one hand, "clank" the coat hanger with a pen or pencil. The sound heard nearby will be barely audible to most. (See Figure 1 below.)

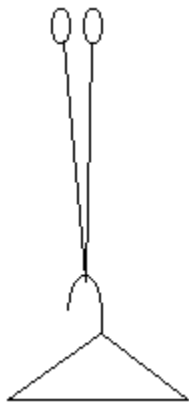


Figure 1



Photo 2

Now have a teammate place his/her index fingers through each loop (one on each hand, as in Photo 2 above) and place the ends of the fingers gently into the ear. Leaning forward to allow the hanger to hang freely, tap it again with a pen or pencil and have the student describe the sound. **Loud, resonating “church bells” (or something rather similar) is often described, once again proving that longitudinal sound waves travel better through solids (the string) than through gases (the air).**

4. **(Teacher-directed)** Now is a good time to mention sound traveling through water (liquid). The sound of someone cracking rocks together while you and the sound source are underwater is quite loud as compared to the audibility of this action above water. Similarly, hearing a motorboat passing by at quite a distance may be barely audible when the observer is above water (air being the medium), yet the sound of the boat’s motor is quite loud when the observer sticks his head below the water’s surface.

Also, students may have seen old Westerns on television where the Indians put their ears to the ground to hear the approach of the cavalry (on horseback) miles away. Why? Once again, proof that sound travels better through solids than through air. Other examples? Doctors and mechanics using stethoscopes to listen to patients’ heartbeats or automotive engine noises. Have your students come up with other examples of where sounds are received through media others than air.

Have your class formulate another hypothesis at this time as to the ranking of the phases of matter according to their ability to transmit sound. Most students will now make amendments to their original “guess.”

The accepted values for the speed of sound ? (Gas) Air = 331-344 meters/sec

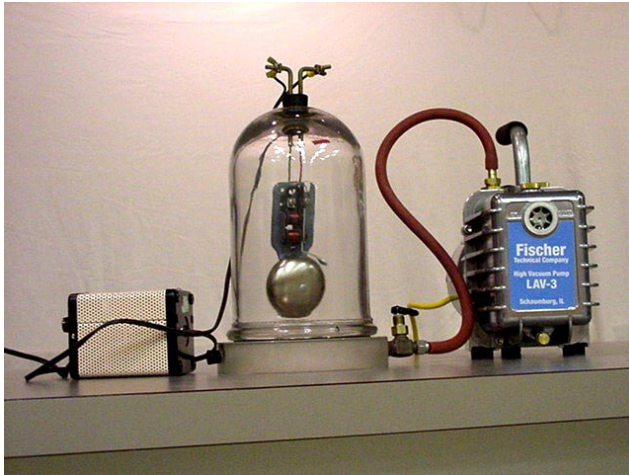
(Liquid) Water = 1441-1724 meters/sec

(Solid) Steel = 4790-4990 meters/sec

(The range of values is dependent upon the material’s temperature. Sound travels faster through warmer substances because the molecules are more energetic at higher temperatures.)

In steel and other solids, the molecules are packed very closely together.... allowing for the compressions and rarefactions to transfer their energy quickly and easily from one molecule to the next. In liquids (such as water), the molecules are further apart, so the compressions have to travel further to pass along their energy. In gases, the molecules are furthest apart...creating a rather slow transfer of energy from molecule to molecule due to the spacing factor and the compressibility of the substance.

5. (Teacher demonstration) Now have the students form a hypothesis as to the ability of a vacuum (a space void of molecules) to transmit sound. Place your sound source (ringing alarm clock, electric bell or other similar device) in the bell jar on top of the vacuum plate. (Or, use the “Bell in Vacuum” assembly mentioned in the **Materials Sources** listing above.)



With air still inside the bell jar, the sound of the alarm will be audible throughout the classroom. Now turn on the vacuum pump for about a minute. The intensity of the sound source will diminish considerably over a period of about a minute (as the vacuum grows stronger)...to the point where students may not hear any sound at all emanating from the bell jar.

6. Have the students predict what will happen to the volume of the sound as air is allowed to re-enter the bell jar. (As air is allowed to re-enter the bell jar, the volume of the sound increases gradually to its original level.) A question can now be raised: If sounds do not travel through a vacuum, how do astronauts communicate with each other when performing repairs on the Hubble Space Telescope? The answer, of course, is via radio communication.